Safety at Seas: Bulk carrier structure

http://antipodeanmariner.blogspot.com/2012/09/safety-at-seas-bulk-carrier-structure.html

Another easy re-post from 'Safety at Sea' with photos from the AM's shipbuilding projects. Acknowledgements to the Author, Captain Dennis Barber and Cliff P. who has annotated some of the cross-sections of the ships under construction and has labeled the main structural components (double-click on the image to get the detail).

Antipodean Mariner

Safety At Sea Magazine Features (6th Sept 2012), Author Captain Dennis Barbour

Bulker safety: Structural strains
A decade ago, the IMO review of bulk carrier safety noted many structural risks facing such vessels. Safety expert Dennis Barber says it is time to review the stresses and strains that bulk carrier hulls still face

The bulk carrier safety debate intensified in the closing years of the 20th century, driven by a continuing attrition of large bulk carriers, many of which disappeared without trace. In response, IMO member states formed the International Collaborative Formal Safety Assessment of Bulk Carriers (FSA), which in the first decade of this century has brought together expertise from various countries and non-governmental organisations. It carried out an intense study using formal safety assessment techniques, and from this emerged measures intended to create safer bulk carriers. Not least of these was the addition of a whole new chapter (XII) to SOLAS that was dedicated to bulk carriers.

Among the many conclusions of the study, the ultimate cause identified for major losses in bulk carriers was loss of hull integrity (LOHI). Vessels of such size could only disappear without trace if they suffered LOHI. Put simply, if a vessel fills with water, it will sink – an obvious conclusion, perhaps, which makes it all the more surprising that LOHI was neglected in regulation until the FSA released its outcomes (for details, see ‘Sink or WIM’, SAS May 2012, p24).

The lack of any distress signal in most of the more than 500 cases studied indicates that the vessels sank rapidly, so must have involved such a massive failure of the hull that the crew had no time to call for help.

The effectiveness of the FSA's work – which has been incorporated into SOLAS Chapter XII and also elsewhere, such as in the International Association of Classification Societies (IACS) Unified Rules – will be tested as time passes. As it is 10 years since the FSA released the first results of its research, with a new generation of seafarers and managers operating the world fleet, it is a good time to review the FSA's findings.

FSA findings revisited

Several dangers were addressed by the FSA. It pointed out that, structurally:

Air pipes, particularly those in the forward part of large bulk carriers, were insufficiently strong to resist the forces to which they could be exposed

Hatch covers were wholly inadequate to withstand the water pressures of over-topping (green) seas

Bulkheads in bulk carriers (as opposed to oil bulk ore carriers) were not strong enough to resist the head of water in a hold flooded to the waterline

Hull shell plating, being a single skin with limited access for close inspection, was highly vulnerable to failure

Freeboard forward was inadequate on low-freeboard vessels such as bulk carriers that were permitted to load to what are known as B-60 freeboards, similar to tankers.

Standards of corrosion control were inadequate to resist the degradation that could weaken shell plating and/or other structures, with the result that they could fail catastrophically.

'Derbyshire', lost with all crew in a typhoon

In the list above the causes of failures were not fully understood. Research into hatch cover failure was, until seafarer input was sought and incorporated, preoccupied with vertical forces. The evidence from the 1980 sinking of Derbyshire suggested that the hatches collapsed under weight of water. This may have been the case and it was officially acknowledged as such, but it was far more likely that the failure of hatches and air pipes came initially from the forward side of the hatch, not from above. Large waves overtopping the forward end would have enormous momentum that would have been capable of dislodging the hatch covers and shearing off the air pipes exposed to the rush of water across the relatively unimpeded foredeck.
Examination of hatch covers that were found in the hold of the wreck suggests this was indeed the cause. The hatch cover skirt was torn out horizontally, indicating that a large force struck it from ahead. Once dislodged, the cover would have been able to fall into the aperture of the forward hold that previously it had been protecting. It is probable that it would also have been exposed to the huge mass of water bearing down on it from above, and this, together with its own weight, would have projected it into the hold.

Forecastle adds reserve buoyancy

Reintroducing the forecastle

One issue that generated much agitation among mariners for many years was the loss of the forecastle in large vessel designs. A majority of modern Capesize and many Panamax bulk carriers are ‘flush-decked’. The mitigating significance of the forecastle was identified by the FSA, but fell foul of the cost-benefit assessment part of the study.

However, IACS took the view that it was worth reintroducing the forecastle. Forecastles on all new bulk carriers were imposed in unified rules that came into force on 1 January 2004. At a stroke, the mariners’ forward shelter was restored, albeit it would take several years for the flush-decked vessels to work their way out of the fleet.

A forecastle offers not only protection to the forward parts of the vessel (and incidentally to seafarers on deck) thus preventing the type of damage to forward hatches referred to above, but also provides valuable reserve buoyancy. The lack of forward reserve buoyancy was also identified in a study submitted by the China delegation at the IMO in 2001 looking at possible deficiencies in the International Convention on Loadlines. The IMO was alerted to the findings at the time of the FSA.

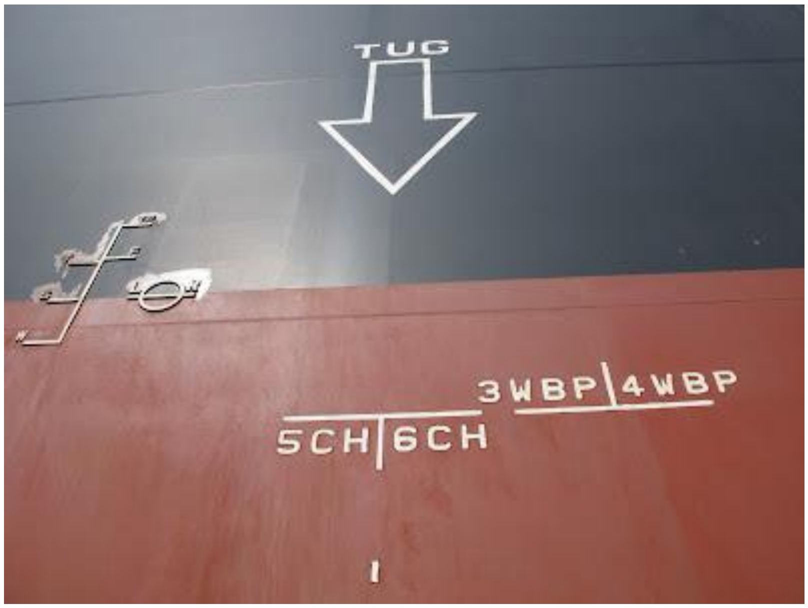
Mariners were not surprised. A favourite and high-scoring question in ship construction papers for the professional mariners’ exams through the greater part of the 20th century was to describe the benefits of a forecastle. It is small wonder that mariners were quick to complain and curious that the design and construction part of the industry failed to see the significance of this simple but effective measure.

This brings us to another structural issue: shell plating strength. Before the 1980s, Capesize vessels typically had a shell plating thickness of 22mm or more, but by the early 1990s this had reduced to a about 15–17mm typically, ostensibly because high-tensile (HT) steel had replaced its low-tensile (LT) equivalent. The FSA revealed that corrosion was a probable factor in failure of shell plating and hatch covers and it should be noted that a 15mm HT steel plate will corrode at the same rate as 22mm LT steel plate. The proportion of degradation, however, is far greater in the thinner plate.

Capesize bulk carrier, annotated by Cliff P.

Berthing difficulties

Modern mariners will be familiar with the marks on the sides of large vessels. The tug pushing points are an admission that the side is not strong enough to resist the force imposed by a tug unless it coincides with a bulkhead. The professionalism of tug masters is thus the main mitigation against damage in this area. In the vast majority of cases, they get it right.



Tug push marks aligned with cargo hold bulkheads

The ship's side is not subjected solely to tug contacts, however. Design tends to concentrate on wave pressures, but this ignores other impacts such as fender pressures during berthing. Fenders fixed to the quayside are much less likely to coincide with bulkheads. If it is the case that the force of a tug pushing on side shell plating between bulkheads can cause damage, how much more potential for damage is there when the total mass of the vessel is concentrated on the single fender that inevitably is the first to make contact during berthing? A Capesize vessel regularly has a loaded displacement of up to 200,000 tonnes. If designers are relying on masters and pilots to ensure the vessel lands 'all along', they are almost certainly expecting the improbable.

Concentrated pressures on shell plating can also be experienced in loading ports where swells are regularly present and where even massive Capesize vessels are always on the move. The vessel's moorings will tend to become slack as the freeboard reduces during loading. Unless kept tight – something that is very difficult during the constant movement imposed by the swells – the vessel will lose contact with the fender face. It will then begin to yaw and alternately make contact at points forward and aft of the midship line. Typically in a nine-hold Capesize bulk carrier these contact points would coincide with No 3 and No 8 hold. It is significant that a number of side shell failures have occurred in these holds.

Spreading the load

With a heavy cargo the failure could be fatal, as a hold already carrying well in excess of 20,000 tonnes of cargo in a small heap in the bottom may take on another 10,000 tonnes of water as it fills the remaining space around the cargo. With a lighter cargo, the vessel may survive. The best mitigation for these potential failures is the avoidance of hard fenders that are concentrated on too small an area of the hull. Because there is no standardisation of hull design, it is impossible to align fenders with bulkheads on the vessels, but it is possible to use large pneumatic fenders that absorb loads and spread them over a larger area – precisely why they are routinely used between large tankers during ship-to-ship transfers. The same principal could be, and in some enlightened ports is, applied between bulk carriers and quaysides.

Some shell-plating failures have occurred in the forward-most hold. This area of the hull is particularly vulnerable on vessels entering locks and docks. The gentle nudge as the bow makes contact at the lock entrance on one shoulder or the other may be transmitting enormous forces into the plating in this area, where the lines of the hull converge towards the bow. A point load exerts pressure on a part of the plating not designed to take any force other than the seas, and the beginnings of a fracture may be imposed on the steel in this area. Failure may not occur straight away, but an undetected fracture may corrode on subsequent voyages until one day the strength of the overall plating fails.

Casualties and a few near-misses have occurred when shell plating around the bow has been breached or, more spectacularly, has fallen away. Such failures are often blamed on wave action – punching into heavy seas – combined with internal corrosion.

The forepeak tank

Another compartment that has a higher likelihood of failure is the forepeak tank, which on a Capesize vessel may be capable of holding 1,200 tonnes or more of ballast water. When the vessel is loaded, this tank would normally be empty, hence the suspicion that punching forces are the primary cause of the failure. Yet if the failure in such cases is invariably caused by external wave forces pushing inwards, the question remains as to why some surviving cases been found with plates distorted outward. The explanation is simple: the primary failure may well have been brought about by punching forces, but these may only have imposed a minor fracture, not a total catastrophic failure. The empty tank would then take on water through the fracture and, though not normally warned against in the vessel’s stability book, sloshing in this tank would begin imposing increasing pressures on the corners of this triangular space as the tank fills.

When the tank is partially full, the pressures may literally blast the side out of the vessel, hence the outward distortions of the plating edges where they have been torn from the side shell. The vessel then suffers a major loss of reserve buoyancy, with the attendant risk of ‘driving under’. This may account for a large number of losses during the night, when the bridge officer is unable to see the seas flooding over the bow. The FSA introduced water ingress monitoring in forepeaks as well as holds, and masters and managers would do well to ensure the systems are tested regularly.

An initial fracture may also result from impacts such as those from swinging anchors during anchoring operations; fractures in way of anchor housings in flush-decked ships where the anchors are very close to the waterline and may cause concentrations of force during punching into seas; and abrasions of anchor chains rubbing against the hull. It is worth noting that salvors use this as a method of cutting up wrecks!

It is evident that a few ports handling Capesize vessels in remote areas use anchor dredging as a means of controlling the vessel during berthing because the ports are not provided with tugs. The damage this could cause to the modern 15mm shell plating should be fully assessed. The ships look the same from the outside as their 22mm predecessors, but the reserve of material is considerably less.

Times change, hazards remain

The high-tensile, low-lightweight ships built in the 1990s are now getting very old and many will be reaching critical strength reduction. More recent vessels will have benefited from improved IMO and IACS regulations and rules, but the hazards remain.

Hold cross section, annotated by Cliff P.

Coatings that are strong and durable have certainly improved resistance to corrosion, but natural forces can still be dangerous. Climate change and the increasing occurrence of storms of unprecedented strength may well be making waves larger. Risks could thus be increasing for these large ships that cannot, because of their length, ride over them.

Mariners clearly have a part to play in ensuring that they learn as much as possible about their ship and its limitations.

Designers can contribute by recognising that they still might not have it exactly right. They could gather data from the mariners and spend more time on ships in ‘the big testing tank’. They could try harder to match the vessels better to their environments, both at sea and in port.

Port designers should perhaps pay closer attention to the way in which they fender their quaysides. That means doing more than ‘ticking the box’ and installing a proprietary fender that its manufacturer insists is suitable. Instead, they should closely observe berthing and calculate the loadings imposed on vessels’ hulls as they make impact, bearing in mind the enormous momentum involved.

Most of all, it is important to continue the work started at the FSA in IMO and to avoid the temptation to let matters stand still as though there is nothing more to be done. When it comes to issue of LOHI, the FSA was the start, not the finish.

Captain Dennis Barber, consulting partner in Marico Marine, was the contracted specialist project manager at the UK MCA for the recommendations of the RFI into the loss of

Derbyshire, serving as part of the project management team of the International Collaborative FSA for Bulk Carriers reporting to the IMO Maritime Safety Committee, 2001–2004